EXECUTIVE SUMMARY

We fished a rotary screw trap in the Stanislaus River near Oakdale, California, during March 18 through July 1, 1995 to monitor the timing and abundance of outmigrating juvenile chinook during large manipulations of river flow. Our index of outmigrant abundance was the daily catch of juvenile chinook divided by the predicted trap efficiency. The abundance of outmigrants was already high when sampling was initiated, and reached its highest during our sampling season on March 26, 3 days after river flow peaked as the result of a substantial freshet. That peak in outmigration lasted only 5 days, then the abundance of outmigrants gradually declined for 10 days. Flows dropped back to 325 cfs within 2 days of the peak flow, 2,090 cfs, and then remained between 208 and 325 cfs until April 8. The abundance of outmigrants jumped sharply again on April 8, coincident with an increase in regulated flow on April 8 from 300 cfs to 600 cfs. The abundance of outmigrants remained elevated for 4 days following the increase in flow. After the river had remained stable at 600 cfs for 7 days, the flow was increased to 1,300 cfs, and the number of outmigrants distinctly increased for only 1 day. River flow then remained stable at about 1,300 cfs from April 15 to June 1. Three additional independent flow spikes, each approximately a 20% increase in flow lasting 2 days, did not stimulate outmigration.

The migratory response of juvenile chinook to a major increase in flow in 1995 was similar to that observed during California Department of Fish and Game's studies in 1994 and our studies in 1993. The pattern in daily outmigration abundance before, during and after artificial increases in flow shows that the stimulatory affect of flow on migration has two characteristics: (1) it lasts only a few days, and (2) it affects only a portion of the population. There is no indication that sustained high flows "flush" juvenile chinook out of the river. Although abundance was low, juvenile chinook continued to migrate out of the river through June.

We conducted a snorkel survey in late June to determine abundance and relative distribution of juvenile chinook, and predator species remaining in the river. Few juvenile chinook remained in the river and predator abundance was low.

We conducted mark-recapture tests with natural migrants captured in the screw trap to determine migration rate and survival from Knights Ferry to Oakdale. Most recoveries in our trap at Oakdale from fish released at Knights Ferry traveld the distance in 2 days. Recaptures of one group of hatchery fish released near Knights Ferry peaked 3 days after release and traveled slower than the natural migrants. Estimated survival to the Oakdale trap of natural chinook varied from 32.4% to 66.7% and was higher for larger fish. Mean lengths at release were 62 mm, 67 mm and 76 mm.

Survival estimates were made for two groups of hatchery chinook released at Knights Ferry and five groups released at Orange Blossom Bridge. Survival of hatchery fish from Knights Ferry to the screw trap at Oakdale was much lower than for natural chinook. Survival estimates of hatchery fish released at Knights Ferry was 8.6% for the larger group (108 mm) and 4.7% for the smaller group (97 mm). Survival estimates for hatchery chinook released at Orange Blossom Bridge ranged from 5.3% to 73.9%. Besides the 73.9%, all survival estimates were less than 15% with an average survival estimate of approximately 9%.

ACKNOWLEDGMENTS

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INTRODUCTION

The California Department of Fish and Game (CDFG) and US Fish and Wildlife Service (USFWS) have requested the release of water to substantially increase Stanislaus River flows during spring since 1989. These flows have usually been released in "pulses" lasting from 2 to 30 days and are intended to increase survival of outmigrating juvenile chinook Salmon (*Oncorhynchus tshawytscha*). These flow related measures require increased use of water from storage reservoirs in the basin. Therefore, Tri-Dam Project, which operates three reservoirs in the Stanislaus River Basin, and the two irrigation districts to which it supplies water, Oakdale and South San Joaquin Irrigation Districts (Joint Districts), sought to develop a pro active role in the fisheries planning process of the San Joaquin River Management Program.

In the fall of 1992, Tri-Dam Project and the Joint Districts retained S.P. Cramer & Associates, fisheries consultants, to advise them on fisheries issues and initiate field studies to estimate fishery benefits derived from flow manipulations. In 1993, we (S.P. Cramer & Associates) fished a rotary screw trap in the Stanislaus River near Oakdale to index the migration timing and abundance of out migrating juvenile chinook during large manipulations in river flow. The trap fished from April 21, 1993 to June 29, 1993. Catches in the trap indicated that out migration peaked for at least one day, but no more than four days, when the Stanislaus River flow increased from 400 cfs on April 22 to 1,400 cfs on April 27. The pattern of daily outmigrant abundance before, during and after the sustained pulse flow events suggested that the stimulatory effect of flow on chinook migration resulted from the change in flow, lasted only a few days, and affected only a small portion of the population (Cramer and Demko 1993). There was no indication that the pulse flows "flushed" juvenile chinook out of the river.

In 1994, the CDFG fished the screw trap near the mouth of the Stanislaus River at Caswell State Park (RM 6). The trap operated from April 23, 1994 to May 26, 1994. Daily catches of juvenile chinook ranged from 0 to 75 (Loudermilk et al. 1995). Catches were highest following the first pulse in flow, (late April), and similarly to 1993, dropped off dramatically within a few days. A second brief increase in catch occurred in late May following a second increase in flow.

Results of the studies in 1993 and 1994 led us to identify several key questions yet to be resolved concerning juvenile chinook outmigration. Most of these questions will require several years of cooperative studies to fully answer. The questions we identified are:

Q1. How high should pulse flows be to stimulate migration?

Q2. How long should pulse flows last to stimulate migration?

Q3. Are there limiting factors before or after the pulse that determine its benefit?

Q4. How long does it take juvenile chinook to migrate out of the Stanislaus River?

Q5. How long does it take juvenile chinook to migrate through the San Joaquin Delta?

Q6. How does flow affect migration rate?

Q7. Will juveniles really stop migrating and be exposed to high mortality in the Delta if pulse flows stop before juveniles pass through the Delta?

Q8. Does smolt-to-adult survival increase with faster migration?

The purpose of the work reported here was to begin answering these questions. To accomplish this, we again fished a rotary-screw trap during the spring of 1995 in the Stanislaus River near Oakdale and conducted mark recapture experiments with juvenile chinook. The report is organized by objectives and tasks. The objectives of the study were to determine the effects natural and modified flow regimes have on the following four parameters:

1. TIMING OF JUVENILE CHINOOK OUTMIGRATION.

Ù RATE OF JUVENILE CHINOOK MIGRATION OUT OF THE STANISLAUS RIVER AND SAN JOAQUIN DELTA.

Ú GROWTH OF JUVENILE CHINOOK.

Û SURVIVAL OF JUVENILE CHINOOK MIGRATING OUT OF THE STANISLAUS RIVER AND SAN JOAQUIN DELTA

DESCRIPTION OF STUDY AREA

The headwaters of the Stanislaus River originate on the western slope of the Sierra Nevada's. The Stanislaus River and its tributaries flow southwest, and enter the San Joaquin River on the floor of the Central Valley (Figure 1). The San Joaquin River flows north and joins the Sacramento River in the Sacramento-San Joaquin Delta. The Stanislaus River is dammed at several locations for the purpose of flood control, power generation and water supply. Water uses include irrigation and municipal needs, as well as recreational activities and water quality control.

Goodwin Dam, approximately 58.4 river miles (RM) upstream from the San Joaquin River confluence, blocks the upstream migration of adult chinook. Almost all chinook spawning occurs upstream of the town of Riverbank (RM 34), and up to Goodwin Dam (RM 58.4).

Throughout this report we reference river miles on the Stanislaus River. River miles were determined with a map wheel and 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987). The estimated river miles of our trapping and release locations are as follows:

Knights Ferry release site	RM 54.7
Orange Blossom Bridge (OBB) release site	RM 46.9
Highway 120/108 release site	RM 41.2
Pipe release site	RM 40.6
Oakdale trapping location	RM 40.1
Caswell Trapping Location	. RM 6

Figure 1. Location map of San Joaquin Basin and Stanislaus River.

METHODS

JUVENILE CHINOOK MIGRATION MONITORING

Oakdale Trapping Site

We fished a rotary screw trap in the mainstem of the Stanislaus River near the Oakdale Recreation Area, approximately 3 miles west of the town of Oakdale, California, for the purpose of capturing juvenile chinook as they migrate downstream. This trap site was chosen because it was the farthest downstream where we could find adequate water velocities for trap operation. Fast water velocities increase the rotation speed of the trap and increases its efficiency for capturing out migrating chinook. This site (RM 40.1) was downstream from the majority of chinook spawning and juvenile rearing, and was the same location we fished in 1993.

The trap, manufactured by E.G. Solutions in Eugene, Oregon, consisted of a funnel shaped core suspended between two pontoons. The trap was positioned in the current so that water enters the 8 ft wide funnel mouth. Water entered the funnel and struck the internal screw core, causing the funnel to rotate. As the funnel rotated, fish were trapped in pockets of water that were forced rearward into a livebox, where fish were held. A 3/8 in. cable was suspended across the river about 35 ft above the water surface to hold the trap in a static position in the main current (Figure 2). Cables fastened to the front of each pontoon were fastened to the overhead cable. This held the trap in position and allowed river users to pass the trap safely.

Figure 2. Photographs of the rotary screw trap sampling near Oakdale. Top photo was taken standing on the right rear pontoon looking upstream. Lower photo is looking downstream at the trap.

We installed the rotary screw trap March 17, and began retrieving catches the morning of March 18. Monitoring continued each morning until the trap was removed July 1. No catch was recorded March 21 and 23, because high debris loading prevented us from fishing the trap. We did not fish the trap June 27, 28 and 29 due to the low number of natural migrants we were catching and the desire to reduce operating costs. We were catching at the time, we assumed that all fish captured in the trap on June 30 and July 1 were unmarked hatchery fish. Because we could not distinguish between the natural migrants and unmarked hatchery fish we released on July 29. Our catches of natural migrants had ranged only from 0 to 4 fish daily since June 15.

We fished the trap 24 hours/day, 7 days/week. Each morning we removed the contents of the livebox and counted, measured and recorded all fish captured. Approximately once per week we removed scales from the first 30 chinook removed from the livebox. A small knife was used to peel away a few scales from the area just posterior to the dorsal fin and above the fishes lateral line. Each sample was placed in a separate envelope with the length of the fish, date, time and smolt index recorded on the outside.

It was often necessary to clean the trap again during mid-day to clear away debris accumulated against the trap and in the livebox. At times of high turbid flows and when we had recently released marked fish, we monitored the trap periodically during the day to document whether or not we were catching juvenile chinook during the day. Following some of the releases, we monitored the trap hourly until 8 a.m. the following morning. For other releases, we monitored the trap every two to four hours, depending on the amount of debris buildup and the number of fish we were capturing.

During natural freshets when fish would accumulate in the livebox fairly rapidly, we monitored the trap every 2 to 3 hours to reduce the chance of mortality to juvenile chinook. Throughout the year we also used a variety of flow deflecting devices in the livebox to provide fish with areas of refuge and to minimize stress and mortality. The most effective mechanism to reduce stress and mortality was a chicken-wire fence stapled to a wood frame, placed in the rear portion of the livebox. The 1 in. octagon mesh, caught wood and plant debris while allowing fish to pass . The debris build up on the fence shielded fish in the rear of the livebox from high water velocities. Bricks and other forms of structure were placed in the live box behind the fence to provide additional shelter.

Smolt Index

We recorded the external appearance of smolting characteristics for each juvenile chinook and rainbow trout measured. Smolting was rated on a scale of 1 to 3, with 1 an obvious parr and 3 an obvious smolt. Smolt characteristics looked for were silveriness, easily shed scales, and a dark band at the margin of the tail fin. Parr characteristics we looked for were lack of silveriness and parr marks on the fish sides.

Experimental Release Groups

A total of 20 groups (12 natural migrants and 8 hatchery releases) were released to estimate trapping efficiency between March 24 and June 29 (Table 1). Between March 24 and May 19, we released 12 separate groups of marked juvenile chinook composed of fish captured in the screw trap. These fish were usually marked the morning of capture and released either that night or the following night. On a few occasions, it was necessary to accumulate fish over several days. Fish were marked by either a partial fin clip or a dye spot. The number of fish in each group ranged from 52 to 235. Fish for trap efficiency tests were always released at dark.

The CDFG also supplied us with juvenile chinook from the Merced River Hatchery for tests of trap efficiency tests on seven occasions (eight separate groups)(Table 1). Hatchery fish were released between April 21 and June 29. The fish were marked with a dye spot at the hatchery by CDFG personnel. Fish were transported to the release site by the Department a few hours prior to release. Fish were held in a net pen in the river and allowed to acclimate for 1 to 6 hours prior to being released at dark. The number of fish in each group of hatchery fish ranged from 106 to 2017.

The CDFG also supplied us with seven groups of fish for tests of migration rate and survival. Five groups were released at Orange Blossom Bridge (OBB; RM 46.9) and two at Knights Ferry (RM 54.7) between May 1 and June 29 (see Table 1). The first five groups were released at OBB at the request of the CDFG. The fish were marked with a dye spot at the Merced River Hatchery by CDFG personnel. The release groups varied in number of fish released from 986 to 2,021.

In addition to the hatchery fish provided us by the CDFG, we also released 3 groups of marked natural migrants at Knights Ferry to determine migration rate and survival from Knights Ferry to the screw trap (see Table 1). The groups were released between March 30 and April 12, and ranged in numbers of fish from 355 to 1,096. The fish were captured in the screw trap and marked with a dye spot.

Table 1. Date, stock, location, time, number of fish released and river flow for trap efficiency, migration rate and survival tests in the Stanislaus River during 1995.

Release Location	Fish Stock	Release Date	Release Time	Mark Released	Number Released	Daily Flow
K.F.	Natural	03/30	1940	tcbn	1096	267
K.F.	Natural	04/04	2100	bcbn	524	274
K.F.	Natural	04/12	2100	afbn	355	586
K.F.	Hatchery	06/14	2030	tcbh6	2009	671
K.F.	Hatchery	06/29	1400	nm	986	250
OBB	Hatchery	05/01	2100	bcbh1	1001	1355
OBB	Hatchery	05/12	2100	bcbh2	1000	1315
OBB	Hatchery	05/19	1930	bcbh3	1018	1345
OBB	Hatchery	05/26	2100	tcbh5	1015	1479
OBB	Hatchery	06/14	2100	bcbh4	2021	671
Pipe	Natural	03/24	2000	rpcn	126	371
Riffle	Natural	03/25	2000	lpcn	200	303
Riffle	Natural	03/26	2000	rvcn	200	286
Pipe	Natural	03/27	2000	lvcn	235	276
Pipe	Natural	03/30	1900	tccn	100	266
Pipe	Natural	03/30	1915	bccn	96	266
Pipe	Natural	04/08	2030	rmcn	81	581
Pipe	Natural	04/10	2100	lmcn	100	580
Pipe	Natural	04/14	2100	tcgn1	52	639
Pipe	Natural	04/21	2045	tcgn2	94	1307
Pipe	Natural	05/16	2100	afgn1	76	1436
Pipe	Natural	05/19	2100	afgn2	93	1345
Hwy 120	Hatchery	04/21	1945	tcbh1	1018	1305
Pipe	Hatchery	05/01	2130	tcbh2	200	1355
Hwy 120	Hatchery	05/12	2200	tcbh3	200	1315
Pipe	Hatchery	05/19	2130	tcbh4	211	1345
Pipe	Hatchery	05/26	2300	tcrh/bcbh	210	1479
Hwy 120	Hatchery	06/14	2300	afbh	2017	671
Pipe	Hatchery	06/15	2200	bcbh/rvch	147	671
Pipe	Hatchery	06/29	2330	lpch	106	250

rpcn = right pectoral clip natural; lpcn = left pectoral clip natural; rvcn = right pelvic (vent) clip natural;
lvnc = left pelvic clip natural; tccn = top caudal clip natural; bccn = bottom caudal clip natural;
rmcn = right maxillary clip natural; lmcn = left maxillary clip natural; tcgn = top caudal green natural;
bcgn = bottom caudal green natural; afgn = anal fin green natural; tcbn = top caudal blue natural;
bcbn = bottom caudal blue natural; afbn = anal fin blue natural; bcbh = bottom caudal blue hatchery;
tcbh = top caudal blue hatchery; nm = no mark.

Holding Facility and Transport Method

Fish used in mark-recapture tests were held prior to release in free standing net pens measuring 4 ft x 4 ft x 4 ft and 2 ft x 3 ft x 3 ft. The net pens consisted of 3/16 in. Delta mesh sewn onto frames constructed of 1/2 in. PVC pipe. The pipe was filled with sand so it would sink and rest on the river bottom. The net pens were located near the trap in an area of low velocity. Net pens were also placed at OBB and Knights Ferry in the river at the release location. Plywood was tied to the top of each pen to prevent fish from escaping and to provide shade for the fish.

Prior to release, fish were transported to the release site in 20 gal. insulated coolers. Between 75 and 150 fish were placed in each cooler and then transported to either Knights Ferry or OBB. Depending on circumstances, the total time fish remained in a cooler ranged from 15 to 35 minutes. Although an aerator was always present in case it was necessary, oxygen was never delivered to the coolers during transport. Fish released ½ mile upstream from the screw trap to test trap efficiency were usually carried to the release location in 20 gal. insulated coolers or 5 gal. plastic buckets.

Marking Procedure

Juvenile chinook were marked with partial fin clips and with dye spots. Before marking, fish were anesthetized with MS-222 (Schoettger 1970). When partial fin clips were used, only the tip of the fin was removed to ensure that the swimming ability of the fish was not impaired. Dye spots were injected into the fins of juvenile chinook with a MadaJet inoculator (Hart and Pitcher 1969). The dyes used were Alcian Blue, Alcian Green and Alcian Red (Sigma Chemical Company, St. Louis, Missouri). The dyes were chosen because of their known ability to provide a highly visible, long lasting mark. Fish were dye-marked by placing the tip of the MadaJet against a fin. Minimal pressure was applied as dye was injected into the fin rays. Fish were marked with a single spot on a single fin. Fin's used were the top caudal, bottom caudal and anal fins.

Prior to any mark-recapture tests, we tested the duration each dye remained visible by marking and holding a small group of fish. After marking, the fish were held for seven days, and none lost their mark. Later in the year, when hatchery fish were available, we marked several groups of hatchery fish to evaluate mark retention and post-marking mortality. Marked fish were held in net pens for as long as 21 days with no loss of marks. Although some post-marking mortality was experienced, it occurred within hours of marking or after 7 to 10 days. For the purposes of conducting mark recapture tests, marked fish which died soon after marking were simply not released and subtracted from the number marked to obtain the number released. We attributed the delayed mortality (weeks) to the stress of captivity rather than the effects of marking. Therefore, we did not make any mortality adjustments to the number of fish released.

Release Procedure

Fish were released at three locations to estimate trapping efficiency; 1) 100 yds upstream of the trap at the head of the riffle, 2) approximately ½ mi upstream from the trap, where the main Oakdale waste pipe crosses over the Stanislaus River, and 3) near the Highway 108/120 bridge, approximately 1.1 miles upstream from the trap. Release site 1) was dropped early in the season because we were concerned that fish released there may not have dispersed across the riffle in their normal fashion by the time they encountered the trap. Prior to release fish were placed in one to three net pens, depending on the number of fish in the release group. Fish were usually allowed to acclimate for one to six hours in the net pen before being released. To release fish, each net pen was gently tipped, and only a few fish were allowed to swim away at a time (groups of approximately 10 fish). The average time to release a complete group was about 10 minutes. All trap efficiency groups were released under total darkness.

Releases designed to determine migration rate and survival were released at OBB (RM 46.9) and Knights Ferry (RM 54.7). The procedure used to release trap efficiency groups was also followed for the Knights Ferry and OBB releases as well. Because the number of fish released was larger at Knights Ferry and OBB, the average release time per group was around 20 to 30 minutes and fish were allowed to swim away in lots up to 25. Fish at Knights Ferry and OBB were always released prior to the trap efficiency groups, and not always under total darkness.

Flow Measurements

Daily flows in the Stanislaus River were obtained from the California Data Exchange Center (CDEC). All river flows cited throughout this report are those measured at the Orange Blossom Bridge by the US Geological Survey (USGS). The flow data are daily averages, and instantaneous flows during freshets were much higher.

We used two methods to index the water velocity entering the trap. From March 18 to April 3, we measured water velocity in front of the trap with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA). From March 18 to July 1, we measured the time, in seconds, per revolution of the trap by using a stopwatch to time three full rotations of the trap.

River Temperature and Relative Turbidity

Daily minimum and maximum Stanislaus River temperature was measured with a mercury thermometer at the trap site. An 8 in. diameter Secchi disk was used to determine relative river turbidity each morning at the trap site by measure the maximum depth at which the disk was visible.

Snorkel Survey

We conducted a snorkel survey on June 22 and 23 to determine the distribution and relative abundance of juvenile chinook remaining in the river above the trap site. We also noted abundance, distribution, and species of predatory fish.

We snorkeled at 5 sites over two consecutive days. We snorkeled Knights Ferry (RM 54.5) and Tullock Road (RM 56.7) on June 22, and OBB (RM 46.6), Honolulu Bar (RM 49.6), Two Mile Bar and Tullock Road on June 23. The actual river miles snorkeled were determined from 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987), and the river miles presented here represent the downstream extent of the surveys. The distances snorkeled were estimated based on partial measurements, and were always greater than 300 meters.

We attempted to locate and snorkel different habitat types at each survey location, (i.e. pool, riffle, run, side channel), but each habitat type did not exist at each survey location. Over the five survey locations, we did sample each habitat type.

Three to four snorkelors counted and recorded fish at each survey site. When possible, we snorkeled habitat units beginning downstream and proceeding upstream. Due to fast water velocities in some areas, we were forced to begin upstream and proceed downstream. The snorkelors were distributed such that each snorkeler was responsible for a different section of the habitat unit, (i.e. right bank, left bank, middle channel, side channel). We classified salmon and trout as "0" and "1+". Fish smaller than 6 in. were classified as age "0", and fish over 6 in. were classified as "1+". Squawfish were classified as juveniles (under 6 in.) or adults (over 6 in.). All other species were counted but not classified by size.

Caswell Trapping Site

In addition to our screw trap near Oakdale, the USFWS fished two screw traps nearer to the mouth of the Stanislaus River, at Caswell State Park (RM 6)(Figure 3). The traps were installed and maintained by the USFWS, and operated from March 27 to May 26. Between May 1 and May 26, we monitored the Caswell traps under contract with the USFWS. All data was collected in accordance with criteria established by the USFWS, and all data was supplied to them weekly. We report the USFWS catch data here in draft format. A full report of the Caswell sampling will be prepared at a later date by the USFWS.

Figure 3. Photographs of the USFWS screw traps sampling at Caswell State Park. Top photo was taken from the west bank. The bottom photo was taken from the rear of the traps looking upstream. The buoys mark the position of under water cables used to hold the traps in place.

RESULTS

Goal: Assess the effects of flow on migration, growth and survival of juvenile chinook in the Stanislaus River.

OBJECTIVE 1: DETERMINE THE EFFECTS NATURAL AND MODIFIED FLOW REGIMES HAVE ON THE TIMING OF JUVENILE CHINOOK OUTMIGRATION.

Task 1.1 Monitor timing of natural juvenile chinook migration.

Time of Chinook Migration

We installed the rotary screw trap March 17, and began retrieving catches the morning of March 18 (Table 2). Monitoring continued until the trap was removed July 1. Daily catches of juvenile chinook ranged from 0 to 1,062, and a total of 10,577 juvenile chinook were captured over the course of sampling. Although the majority of juvenile chinook were captured at night, a few were captured during daylight at times of high, turbid river flows. Catches of juvenile chinook peaked soon after installation of the trap, when high precipitation resulted in increased turbidity and a spike in flow on March 23 (Figure 4). The majority of juvenile chinook migrated out of the upper river during and immediately following this spike in flow.

Table 2. Daily screw trap sampling data. The expanded index equals the chinook catch divided by the trapping efficiency.

Date	Flow	Chinook Catch	Estimated Efficiency (%)	Expanded Index	Date	Flow	Chinook Catch	Estimated Efficiency (%)	Expanded Index
18-Mar	278	543	21.5	2,526	10-May	1463	22	8.5	259
19-Mar	276	653	21.6	3,023	11-May	1313	36	9.5	379
20-Mar	347	392	20.4	1,922	12-May	1315	78	9.5	821
21-Mar	480	330	18.4	1,793	13-May	1353	49	9.3	527
22-Mar	612	268	16.6	1,614	14-May	1366	76	9.2	826
23-Mar	2090	243	8	3,038	15-May	1389	27	9	300
24-Mar	850	217	13.7	1,584	16-May	1413	38	8.8	432
25-Mar	325	565	20.8	2,716	17-May	1424	65	8.8	739
26-Mar	295	1062	21.3	4,986	18-May	1370	75	9.1	824
27-Mar	287	616	21.4	2,879	19-May	1345	81	9.3	871
28-Mar	273	692	21.6	3,204	20-May	1334	82	9.4	872
29-Mar	270	474	21.7	2,184	21-May	1328	49	9.4	521
30-Mar	267	197	21.7	908	22-May	1347	25	9.3	269
31-Mar	264	140	21.8	642	23-May	1329	52	9.4	553
01-Apr	224	75	22.5	333	24-May	1305	27	9.6	281
02-Apr	208	104	22.8	456	25-May	1311	30	9.6	313
03-Apr	209	133	22.7	586	26-May	1479	27	8.4	321
04-Apr	274	103	21.6	477	27-May	1626	18	8	225
05-Apr	302	113	21.1	536	28-May	1482	13	8.4	155
06-Apr	297	77	21.7	355	29-May	1347	6	9.3	65
07-Apr	320	67	20.8	322	30-May	1338	22	9.4	234
08-Apr	578	295	17	1,735	31-May	1326	11	9.5	116
09-Apr	581	242	17	1,424	01-Jun	1185	12	10.6	113
10-Apr	582	314	17	1,847	02-Jun	889	8	13.3	60
11-Apr	586	239	16.9	1,414	03-Jun	673	49	15.8	310
12-Apr	586	62	16.9	367	04-Jun	679	35	15.7	223

13-Apr	590	74	16.9	438	05-Jun	684	15	15.7	96
14-Apr	589	95	16.9	562	06-Jun	678	17	15.7	108
15-Apr	1117	115	11.1	1,036	07-Jun	684	24	15.7	153
16-Apr	1347	24	9.3	258	08-Jun	688	15	15.6	96
17-Apr	1328	66	9.4	702	09-Jun	674	18	15.8	114
18-Apr	1311	22	9.6	229	10-Jun	666	9	15.9	57
19-Apr	1301	46	9.6	479	11-Jun	675	17	15.8	108
20-Apr	1308	22	9.6	229	12-Jun	678	11	15.7	70
21-Apr	1305	39	9.6	406	13-Jun	682	12	15.7	76
22-Apr	1305	54	9.6	563	14-Jun	671	8	15.8	51
23-Apr	1301	36	9.6	375	15-Jun	606	3	16.6	18
24-Apr	1304	42	9.6	438	16-Jun	352	0	20.3	0
25-Apr	1409	48	8.9	539	17-Jun	271	2	21.7	9
26-Apr	1607	47	8	588	18-Jun	246	4	22.1	18
27-Apr	1516	21	8	263	19-Jun	245	2	22.1	9
28-Apr	1303	27	9.6	281	20-Jun	240	3	22.2	14
29-Apr	1312	19	9.6	198	21-Jun	237	4	22.3	18
30-Apr	1318	20	9.5	211	22-Jun	250	3	22	14
01-May	1355	20	9.2	217	23-Jun	268	3	21.7	14
02-May	1338	33	9.4	351	24-Jun	237	4	22.3	18
03-May	1332	46	9.4	489	25-Jun	238	0	22.2	0
04-May	1319	69	9.5	726	26-Jun	234	2	22.3	9
05-May	1316	28	9.5	295	27-Jun	239	ND	-	-
06-May	1339	35	9.4	372	28-Jun	246	ND	-	-
07-May	1323	34	9.5	358	29-Jun	250	ND	-	-
08-May	1460	41	8.5	482	30-Jun	266	ND	-	-
09-May	1588	49	8	613	01-Jul	282	ND	-	-

Figure 4. Daily number of juvenile chinook captured in the screw trap and river flow at OBB.

Trap Efficiency

Trap efficiency was tested with both natural migrants and hatchery reared juvenile chinook. Between March 24 and May 19, we released 12 groups of marked natural migrants to estimate trapping efficiency (Table 3). Fish were released at flows ranging from 266 cfs to 1,436 cfs. The percentage of the released fish recovered in the screw trap varied from 0 to 44.8%. Between April 21 and June 29 we released 8 groups of marked hatchery fish to estimate trapping efficiency (see Table 3), at flows ranging from 250 cfs to 1,479 cfs. The percentage of the released fish recovered in the screw trap varied from 7.5 to 29.2%.

Trapping efficiency was negatively correlated to flow, although there was substantial variation in trapping efficiency at any give flow (Figure 5). A regression of ...... accounted for % of the variation in trap efficiency. Trap efficiency tests with natural and hatchery fish showed similar variation around the regression line (Figure 5). We used the regression of trap efficiency on flow to estimate average efficiency each day. Estimated trap efficiency varied from 22.9% at 200 cfs to 8.2% at 1,500 cfs (Figure 5). We did not test trap efficiency at flows higher than 1,500 cfs, so we did not use the regression to estimate trap efficiency beyond 1,500 cfs. Instead we assumed that trapping efficiency was 8.0% at flows higher than 1,500 cfs (see Table 2). Flows exceeded 1,500 cfs on only five days during the season, and the maximum flow was 1,626 cfs.

Table 3. **Mark recapture data for all fish released during 1995.** Chinook released at the “Riffle”, "Pipe" and "Hwy 120" locations were released to determine trap efficiency. Fish released at Knights Ferry and OBB were released for migration rate and survival experiments.

Release Location	Fish Stock	Release Date	Mark Released	Release Time	Daily Flow	Mark Retention	Number Released	Adjusted Release #	Raw Number Recaptured	Raw Percent Recaptured
K.F.	Natural	03/30	tcbn	1940	267	100%	1096	1096	77	7.0
K.F.	Natural	04/04	bcbn	2100	274	100%	524	524	67	12.8
K.F.	Natural	04/12	afbn	2100	586	100%	355	355	40	11.3
K.F.	Hatchery	06/14	tcbh6	2030	671	100%	2009	2009	15	0.7
K.F.	Hatchery	06/29	nm	1400	250	97%	986	956	18	1.9
OBB	Hatchery	05/01	bcbh1	2100	1355	*100%	1001	1001	7	0.7
OBB	Hatchery	05/12	bcbh2	2100	1315	*100%	1000	1000	10	1.0
OBB	Hatchery	05/19	bcbh3	1930	1345	*100%	1018	1018	5	0.5
OBB	Hatchery	05/26	tcbh5	2100	1479	90%	1015	914	11	1.2
OBB	Hatchery	06/14	bcbh4	2100	671	97%	2021	1960	229	11.7

Pipe	Natural	03/24	rpcn	2000	371	100%	126	126	13	10.3
Riffle	Natural	03/25	lpcn	2000	303	100%	200	200	37	18.5
Riffle	Natural	03/26	rvcn	2000	286	100%	200	200	62	31.0
Pipe	Natural	03/27	lvcn	2000	276	100%	235	235	26	11.1
Pipe	Natural	03/30	tccn	1900	266	100%	100	100	48	48.0
Pipe	Natural	03/30	bccn	1915	266	100%	96	96	43	44.8
Pipe	Natural	04/08	rmcn	2030	581	100%	81	81	25	30.9
Pipe	Natural	04/10	lmcn	2100	580	100%	100	100	22	22.0
Pipe	Natural	04/14	tcgn1	2100	639	100%	52	52	5	9.6
Pipe	Natural	04/21	tcgn2	2045	1307	100%	94	94	9	9.6
Pipe	Natural	05/16	afgn1	2100	1436	100%	76	76	0	0.0
Pipe	Natural	05/19	afgn2	2100	1345	100%	93	93	0	0.0
Hwy 120	Hatchery	04/21	tcbh1	1945	1305	*100%	1018	1018	76	7.5
Pipe	Hatchery	05/01	tcbh2	2130	1355	*100%	200	200	32	16.0
Hwy 120	Hatchery	05/12	tcbh3	2200	1315	*100%	200	200	50	25.0
Pipe	Hatchery	05/19	tcbh4	2130	1345	*100%	211	211	29	13.7
Pipe	Hatchery	05/26	tcrh/bcbh	2300	1479	72%	210	151	8	5.3
Hwy 120	Hatchery	06/14	afbh	2300	671	100%	2017	2017	223	11.1
Pipe	Hatchery	06/14	bcbh/rvch	2200	671	100%	147	147	14	9.5
Pipe	Hatchery	06/29	lpch	2330	250	100%	106	106	31	29.2

* No mark retention sampling was conducted. Assumed 100% retention.

Figure 5. Relationship of screw trap efficiency and Stanislaus River flow at OBB. Solid line represents predicted trap efficiency base on exponential regression.

Size Selectivity of Screw Trap

We examined mean lengths of chinook prior to release and mean lengths at recapture to determine if there was evidence that the trap tended to catch more of the smaller or larger fish from a release group. Mean lengths of fish released for trap efficiency tests (both natural and hatchery fish) were not significantly different from the mean lengths recaptured (t = .16; Table 4), indicating the trap sampled different sizes of chinook equally.

Smolt Outmigration Index

Because trapping efficiency varied as flow varied, we converted our raw trap catches to an index of total outmigrants by the expression:

$$\text{Outmigrant Index} = 3\ \text{Daily Catch}_i / \text{Predicted Trap Efficiency}_i$$

where,

Daily Catch = no. fish captured in the screw trap each day,

Predicted Trap Efficiency =predicted by regression on daily river flow.

I = Day of catch

The trend in the daily chinook index is similar to that in the daily catch (Figure 6 and Table 2). The daily outmigration index peaked on March 26, the day of highest raw catch in the trap. Based on the daily outmigration index, we estimate that 4,986 juvenile chinook migrated past the trap that night and a total of 66,245 from March 18 to July 1. The index of outmigrants peaked again April 8-11, but at a lesser level (Figure 6).

Table 4. Mean lengths of fish released and recaptured for all test groups.

Release Location	Fish Stock	Release Date	Mark Released	Release Time	Mean Length Released (mm)	Mean Length Recaptured (mm)	Recapture minus Release (mm)
K.F.	Natural	03/30	tcbn	1940	62	73	11
K.F.	Natural	04/04	bcbn	2100	67	75	8
K.F.	Natural	04/12	afbn	2100	76	79	3
K.F.	Hatchery	06/14	tcbh6	2030	97	98	1
K.F.	Hatchery	06/29	nm	1400	108	106	-2
OBB	Hatchery	05/01	bcbh1	2100	80	82	2
OBB	Hatchery	05/12	bcbh2	2100	83	84	1
OBB	Hatchery	05/19	bcbh3	1930	86	82	-4
OBB	Hatchery	05/26	tcbh5	2100	88	89	1
OBB	Hatchery	06/14	bcbh4	2100	92	96	4

Pipe	Natural	03/24	rpcn	2000	56	56	0
Riffle	Natural	03/25	lpcn	2000	60	65	5
Riffle	Natural	03/26	rvcn	2000	60	ND	-
Pipe	Natural	03/27	lvcn	2000	64	65	1
Pipe	Natural	03/30	tccn	1900	60	65	5
Pipe	Natural	03/30	bccn	1915	60	65	5
Pipe	Natural	04/08	rmcn	2030	76	74	-2
Pipe	Natural	04/10	lmcn	2100	78	82	4
Pipe	Natural	04/14	tcgn1	2100	72	78	6
Pipe	Natural	04/21	tcgn2	2045	81	78	-3
Pipe	Natural	05/16	afgn1	2100	98	-	-
Pipe	Natural	05/19	afgn2	2100	96	-	-
Hwy 120	Hatchery	04/21	tcbh1	1945	72	72	0
Pipe	Hatchery	05/01	tcbh2	2130	79	79	0
Hwy 120	Hatchery	05/12	tcbh3	2200	79	83	4
Pipe	Hatchery	05/19	tcbh4	2130	84	88	4
Pipe	Hatchery	05/26	tcrh/bcbh	2300	88	92	4
Hwy 120	Hatchery	06/14	afbh	2300	97	98	1
Pipe	Hatchery	06/14	bcbh/rvch	2200	100	101	1
Pipe	Hatchery	06/29	lpch	2330	108	108	0

Figure 6. Comparison of daily chinook catch and the chinook abundance index at Oakdale rotary-screw trap in 1995.

Task 1.2 Quantify the influence of flow on chinook migration timing.

Influence of Flow on Chinook Outmigration

Flow changed sharply several times during the period of our sampling, both as a result of natural (runoff) and managed (release of stored water) events. The highest flow we sampled was almost 2,100 cfs and occurred within the first week of sampling (see Figure 6). Outflows from Goodwin Dam remained stable during that time, so the spike in flow resulted from natural runoff below Goodwin Dam. Flow dropped sharply after that spike and then remained between 208 cfs to 325 cfs during March 25 through April 7. Managed increases in flow began on April 8. Flow increased to about 600 cfs for seven days. At the direction of fisheries agencies, flows were sustained at approximately 1,300 cfs during April 16 - May 31 and were intended to encourage chinook to migrate out of the river and to increase their survival through the Delta. During the 6 weeks of sustained 1,300 cfs flow, there were three small spikes in flow, reaching 1,600 cfs for about 48 hours each. These small spikes (about a 20% increase in flow) were tested to determine if they would stimulate chinook migration.

At least two peaks in outmigration were associated with sharp changes in flow. The highest peak in outmigration occurred during March 26-28 (see Figure 6), following the sharp drop in flow after brief spike in natural runoff of over 2,000 cfs on March 23. The outmigration index peaked three days after that peak flow event, when flow had returned to about 300 cfs, and lasted only a few days. The outmigration index peaked sharply again about two weeks later (April 8 - 11), this time coincident with an artificial increase in flow from about 300 cfs to 600 cfs. Although the flow remained near 600 cfs for 7 days, the outmigration index remained high for only 4 days. AA third and lesser peak in the outmigrant index, lasting only one day occurred the first day hat flows increased again from 589 cfs to 1,117 cfs. That was April 15. The 6 week period of 1,300 cfs flow began on April 15. The outmigrant index fluctuated at a lower level throughout the six weeks of high flow. There was no change in the outmigration index that was consistent with the three short duration pulses of 1,600 cfs.

Influence of Turbidity on Chinook Outmigration

There was variation in relative river turbidity (secchi depth) between days which was probably due to the subjective nature of the reading rather than true variation in river turbidity. As a general rule, river turbidity increased (secchi depth decreased) as flow increased (Figure 7). Both of the major spikes in abundance of outmigrants (March 25 to March 28 and April 8 to April 11) coincided with periods of high turbidity (Figure 8). However, there were no spikes in abundance of outmigrants during dates of equally high turbidity during April (Figure 8).

Figure 7. **Relationship of turbidity to flow in the Stanislaus River during 1995. Secchi depth measured at Oakdale and flow at Orange Blossom Bridge.**

Figure 8. **Comparison of the daily abundance index for chinook outmigrants to the river turbidity at Oakdale, 1995.**

Influence of Fish Length on Chinook Outmigration

The mean lengths of chinook captured in the screw trap increased gradually from about 60 mm at the beginning of sampling to over 100 mm by June (Figure 9). Mean lengths of fish during the peaks in outmigration during late March and again in early April were 60 mm and 76 mm, respectively.

In March and early April we captured 16 yearling chinook. We distinguished "yearlings" based on their large sizes relative to the length of the majority of the chinook we were catching at the time. All of the yearlings captured had advanced smolting characteristics (i.e. scales and darkened anal and dorsal fin tips). We captured the first yearling chinook on March 18 and the last on April 9 (Figure 10).

Figure 9. **Daily minimum, maximum and mean lengths of chinook captured in the screw trap. Yearling chinook were included in the daily mean length calculation only when they were present in the sub-sample of 30 fish measured each morning.**

Figure 10. **Daily mean length of the first 30 chinook removed from the trap and the individual lengths of all yearling chinook captured in the trap.** In addition to measuring the first 30 fish removed from the trap, we measured all fish that were either larger or smaller than the usual length range

Influence of River Temperature on Chinook Outmigration

The Stanislaus River temperature at Oakdale did not surpass 60° F until the second week of June, well after the majority of juvenile chinook had migrated out of the river (Figure 11). River temperature varied little during substantial variation in the abundance index of chinook outmigrants.

Influence of smolting on Chinook Outmigration

We estimated the degree of smolting for each natural migrant captured based on external characteristics. The smolt index (SI) for each fish was used to calculate a daily smolting index by the expression:

daily chinook smolting index = 1 * (# chinook SI 1) + 2 * (# chinook SI 2) +
3 * (# chinook SI 3) / number of chinook rated each day.

The degree of smolting of fish captured in the trap increased as sampling progressed (Figure 12 and Appendix 1). The smolting index was lowest for the season during late March and early April when the abundance of outmigrants was greatest. Thus, there was no relationship between the external appearance of smolting and the abundance index of outmigrants.

Rainbow/Steelhead Trout

We captured a total of 23 rainbow trout (*Oncorhynchus mykiss*) in the screw trap in

1995 (Figure 13). Eighteen of the fish showed advanced signs of smolting and three showed no signs of smolting (Appendix 2). Species other than salmon and trout captured in the screw trap are listed in Appendix 3.

Figure 11. Daily chinook migration index and maximum Stanislaus River temperature. The temperature was monitored 24 hours per day at the trap site with a min/max thermometer.

Figure 12. Daily juvenile chinook salmon smolting index.

Figure 13. Dates of capture and lengths of rainbow trout/steelhead captured in the screw trap.

OBJECTIVE 2: DETERMINE THE EFFECTS NATURAL AND MODIFIED FLOW REGIMES HAVE ON THE RATE OF JUVENILE CHINOOK MIGRATION OUT OF THE STANISLAUS RIVER AND SAN JOAQUIN DELTA.

Task 2.1 Determine the rate of juvenile chinook migration in the Stanislaus River.

We determined the rate at which juvenile chinook migrate by releasing them upstream and recapturing them downstream. Because few of these fish were captured at Caswell trap, we could not determine migration rates through the entire river.

Mark and Release of Naturally Migrating Chinook

We marked and released natural migrants at Knights Ferry to determine the rate at which they migrate from Knights Ferry to the screw trap (14.6 miles). Three groups of natural migrants were released at Knights Ferry between March 30 and April 12. Fish were released at river flows of 267 cfs, 274 cfs and 586 cfs. Although more releases were desired, we stopped marking natural migrants in mid April at the request of USFWS.

For each group, recaptures in the Oakdale trap peaked two days after release (Table 5). The duration over which we recaptured marked fish was most protracted for the smallest fish released (March 30 group) and least protracted for the largest fish we released (April 12 group)(Figure 14).

Table 5. Time of peak recapture for all marked fish released in 1995.

Release Location	Fish Stock	Release Date	Mark Released	Release Time	Flow on Release Day (cfs)	Time until Peak Recapture (Days)	Last Recapture (Days)	Raw Percent Recaptured
K.F.	Natural	03/30	tcbn	1940	267	2	33	7
K.F.	Natural	04/04	bcbn	2100	274	2	10	12.8
K.F.	Natural	04/12	afbn	2100	586	2	6	11.3
K.F.	Hatchery	06/14	tcbh6	2030	671	3	5	0.7
K.F.	Hatchery	06/29	nm	1400	250	2	2	1.7
OBB	Hatchery	05/01	bcbh1	2100	1,355	2	4	0.7
OBB	Hatchery	05/12	bcbh2	2100	1,315	1	1	1
OBB	Hatchery	05/19	bcbh3	1930	1,345	1	1	0.5
OBB	Hatchery	05/26	tcbh5	2100	1,479	1	2	1.1
OBB	Hatchery	06/14	bcbh4	2100	671	1	1	11.3
Pipe	Natural	03/24	rpcn	2000	371	1	4	10.3
Riffle	Natural	03/25	lpcn	2000	303	1	4	18.5
Riffle	Natural	03/26	rvcn	2000	286	1	1	31
Pipe	Natural	03/27	lvcn	2000	276	1	1	11.1
Pipe	Natural	03/30	tccn	1900	266	1	10	48
Pipe	Natural	03/30	bccn	1915	266	1	5	44.8
Pipe	Natural	04/08	rmcn	2030	581	1	1	30.9
Pipe	Natural	04/10	lmcn	2100	580	1	2	22
Pipe	Natural	04/14	tcgn1	2100	639	1	1	9.6
Pipe	Natural	04/21	tcgn2	2045	1,307	1	1	9.6
Pipe	Natural	05/16	afgn1	2100	1,436	-	-	0
Pipe	Natural	05/19	afgn2	2100	1,345	-	-	0
Hwy 120	Hatchery	04/21	tcbh1	1945	1,305	1	2	7.5
Pipe	Hatchery	05/01	tcbh2	2130	1,355	1	2	16
Hwy 120	Hatchery	05/12	tcbh3	2200	1,315	1	2	25

Pipe	Hatchery	05/19	tcbh4	2130	1,345	1	2	13.7
Pipe	Hatchery	05/26	tcrh/bcbh	2300	1,479	1	1	3.8
Hwy 120	Hatchery	06/14	afbh	2300	671	1	1	11.1
Pipe	Hatchery	06/15	bcbh/rvch	2200	671	1	1	9.5
Pipe	Hatchery	06/29	lpch	2330	250	1	1	29.2

Release pipe to trap = .5 mi
Hwy 120/108 to trap = 1.1 mi
OBB to trap = 6.8 mi
Knights Ferry to trap = 14.6 mi

Figure 14. Relative frequency of migration times for three groups of marked natural chinook to reach the trap at Oakdale after release at Knights Ferry, 14.6 miles upstream.

Mark and Release of Hatchery Chinook

We also and released marked hatchery fish at Knights Ferry and at Orange Blossom Bridge (OBB) to determine the rate at which they migrate downstream to the screw trap (14.6 miles and 6.8 miles, respectively). Groups of hatchery fish were released at Knights Ferry on June 14 at a flow of 671 cfs and June 29 at a flow of 250 cfs.

Recaptures from the June 14 release at Knights Ferry did not peak until 3 days after release and were the only group released that did not peak on the first or second day following release. In spite of their large size at release (98 mm) and high river flow (671 cfs) they migrated much slower than the natural migrants released in April at the same location (Table 6). We did not calculate average migration rate for the group of unmarked hatchery fish released on June 29.

Table 6. Average speed (mph) of migration for hatchery and natural chinook released at Knights Ferry and Orange Blossom Bridge.

Task 2.2 ***Determine rate of chinook migration through the San Joaquin Delta.***

The rate of chinook migration through the Delta can be inferred from CDFG and USFWS trawls at Mossdale and Chipps Island of Coded Wire Tag (CWT) fish released at various locations in the Delta, San Joaquin River and tributaries. Large numbers of CWT marked hatchery chinook were released this year in the Merced and Toulumne Rivers and some were captured at Chipps Island. No CWT marked groups were released in the Stanislaus River this year. Fish released in either the upper or lower Merced during the first week in May arrived at Chipps Island between 2.5 to 4.5 weeks later (Figure 15). The pattern was similar for fish released in the upper and lower Toulumne River (Figure 15). We cannot directly estimate the portion of this migration time that was spent in the Delta.

Figure 15. Number of CWT chinook juveniles recovered on each day of trawl sampling at Chipps Island from fish released in the Merced (upper graph) and Tuolomne rivers (lower graph) during 1995.

OBJECTIVE 3: DETERMINE THE EFFECT THAT FLOW HAS ON GROWTH OF JUVENILE CHINOOK.

Task 3.1 Determine if flow influences growth of juvenile chinook.

Studies have shown that it is difficult to accurately determine environmental effects on growth rate in natural populations of juvenile chinook within a single season. The size related tendency to migrate displayed by juvenile chinook confounds identifying differences in growth between weeks. Therefore, this task will be accomplished with multiple years of sampling.

Juvenile chinook lay down a new circulus on their scales about every 10 days. Average spacing between these circuli for bands of five circuli (50 days) have been demonstrated to be highly correlated to growth rate. Therefore, scale circuli spacing provides a measure of growth for a single season and will be useful for comparison to future seasons with different environmental conditions.

We removed scales from chinook captured in the screw trap approximately once per week. These scales will be interpreted by SPCA or CDFG in the future, possibly at the same time the large collection of scales collected by the CDFG are interpreted. The CDFG has been collecting San Joaquin chinook scales for several years that have not been interpreted.

OBJECTIVE 4: DETERMINE THE EFFECTS OF NATURAL AND MODIFIED FLOW REGIMES ON SURVIVAL OF JUVENILE CHINOOK MIGRATING OUT OF THE STANISLAUS RIVER AND SAN JOAQUIN DELTA.

Task 4.1 ***Determine survival of migrating juvenile chinook in the Stanislaus River***.

Survival of juvenile chinook during migration through the Stanislaus River was to be estimated from the release and recovery of marked natural and hatchery chinook. However, only six of our marked fish were recovered at the Caswell trap, so we could not estimate survival through the entire river. An index of chinook survival during migration from the Knights Ferry (RM 54.7), and from OBB (RM 46.9) to the Oakdale trap (RM 40.1) was estimated by the expression:

Survival = R / (E * M)

where

Survival = the estimated proportion of fish surviving to reach the trap

R = the number of marked fish recaptured in the trap

E = efficiency of the trap based on exponential regression of trap efficiency tests and flow

M = number of marked fish released.

A number of assumptions are inherent in this estimate. Among them are the following:

- Marked and unmarked fish are equally vulnerable to capture in the trap.
- Marked and unmarked fish experience equal mortality rates.
- All marks remain visible and are observed at the Oakdale trap.
- No fish remained upstream of the trap at the conclusion of sampling.

We cannot verify how well these assumptions were met, so we refer to our survival estimate as a survival index. True survival during outmigration was likely higher than our estimates because we know that some chinook remained above our trap when sampling concluded. Additionally, some marks may have faded or been overloaded at the time they were captured in our trap.

Marked Groups of Naturally Migrating Chinook

We released marked natural chinook on three separate occasions at Knights Ferry to determine juvenile chinook survival from Knights Ferry to the trap location (14.6 miles, Table 7). Fish were release at three different flows, 267 cfs, 274 cfs and 586 cfs. The survival index was estimated at 32.4%, 59.2% and 66.7%, respectively (Table 7). Although the survival index increased as flow increased, survival was most highly correlated (r = 0.89) to the size of chinook at release (Figure 16). Additionally, the mean lengths of the fish recaptured were significantly ($P < 0.05$) greater than the mean of fish released from both the first and second groups.

Table 7. Survival estimates for natural chinook released at Knights Ferry and hatchery chinook released at knights Ferry and OBB.

Release Location	Fish Stock	Release Date	Mark Released	Release Time	Daily Flow	Mark Retention	Number Released	Adjusted Release #	Raw Number Recaptured	Raw Percent Recaptured	Estimated Trap Efficiency	Expanded Number Recaptured	Expanded Percent Recaptured
K.F.	Natural	03/30	tcbn	1940	267	100%	1096	1096	77	7.0	21.7	355	32.4
K.F.	Natural	04/04	bcbn	2100	274	100%	524	524	67	12.8	21.6	310	59.2
K.F.	Natural	04/12	afbn	2100	586	100%	355	355	40	11.3	16.9	237	66.7
K.F.	Hatchery	06/14	tcbh6	2030	671	100%	2009	2009	15	0.7	15.8	95	4.7
K.F.	Hatchery	06/29	nm	1400	250	97%	986	956	18	1.9	22	82	8.6

OBB	Hatchery	05/01	bcbh1	2100	1355	*100%	1001	1001	7	0.7	9.2	76	7.6
OBB	Hatchery	05/12	bcbh2	2100	1315	*100%	1000	1000	10	1.0	9.5	105	10.5
OBB	Hatchery	05/19	bcbh3	1930	1345	*100%	1018	1018	5	0.5	9.3	54	5.3
OBB	Hatchery	05/26	tcbh5	2100	1479	90%	1015	914	11	1.2	8.4	131	14.3
OBB	Hatchery	06/14	bcbh4	2100	671	97%	2021	1960	229	11.7	15.8	1449	73.9

* No mark retention sampling was conducted. Assumed 100% retention.

Figure 16. Survival of natural juvenile chinook released at Knights Ferry.

Figure 17. Mean lengths at release and recapture for hatchery and natural fish released at Knights Ferry.

Marked Groups of Hatchery Fish

Marked hatchery fish were released at Knights Ferry on two occasions and at OBB on five occasions to determine survival of hatchery fish from Knights Ferry and OBB to the trap (14.6 miles and 6.8 miles, respectively). Estimated survival for the June 14 release group was 4.7%, compared to 8.6% for the group released June 29. These survival rates are in the range of one tenth the expected survival index for natural fish, based on their size and the results in Figure 15.

Because the percentage of hatchery fish recovered from releases at Knights Ferry was less than 10%, variation in the number of fish recovered should be approximated by the Poison distribution (Ricker 1975). The 95% confidence limits for the number of fish recovered according to the Poisson distribution, would be 8.4 to 24.8 for 15 fish recovered from the June 14 release, and 10.7 to 28.4 for the 18 fish recovered from the June 29 release. After the sampling error in our estimates of trap efficiency are added to the Poisson variation in number of fish recovered, there would be no statistical basis for regarding the survival indexes on the two dates as different from each other.

Estimated survival for the five hatchery groups released at OBB ranged widely from 5.3% to 73.9% (Table 7). Four of the five releases were conducted at similar river flows, 1,315 cfs to 1,479 cfs, and produced relatively uniform survival ranging from 7.6% to 14.3% (Table 7). The survival index for the last group released at OBB on June 14 was substantially higher at 73.9%.

Figure 20. Mean lengths at release and recapture for hatchery fish released at Orange Blossom Bridge.

DISCUSSION

PULSE FLOW EFFECTS

There were four general questions regarding the stimulatory effect of pulse flows on juvenile chinook migration that motivated our field investigations of juvenile outmigrations during 1995. Accordingly, our discussion of pulse flow effects is divided under these questions.

How high should pulse flows be to stimulate migration?

Results from sampling of juvenile chinook outmigrants in 1995 provided new insight toward the question, “How high should pulse flows be to stimulate migration?” A sharp increase in the abundance of outmigrants was stimulated by an increase in flow on April 8 from 320 cfs to 578 cfs (see Figure 7). This increase in flow was artificailly generated by release of stored water from upstream reservoirs, and follwed a 14 day period of stable flows ranging from 208 cfs to 325 cfs. The chinook outmigrant index at the Oakdale trap had ranged from 322 fish to 642 fish for the previous 10 days, and then jumped to 1,735 fish on April 8, the day flows increased by 258 cfs (see Table 2). Flows remained near 580 cfs for 7 days, starting April 8, and the outmigrant index remained elevated between 1,414 and 1,847 for 4 days.

Catches by the USFWS in the screw traps at Caswell State Park, 34 miles downstream from Oakdale, also show that the initial artificial flow spike to 600 cfs stimulated chinook to migrate, and only for a few days (Figure 21). The increase in flow reached Caswell Park on April 10, and catches of juvenile chinook jumped to 107 - 133 fish/day for the next 3 days after ranging from 38 to 56 for the previous 12 days. Similar to the results at the Oakdale trap in 1995, the catches at the Caswell traps remained at elevated levels for only 5 days, and then remained at lower levels for the ramainder of the season.

Figure 21. Daily catch of juvenile chinook in the screw traps near Caswell State Park in 1995. Flow is Stanislaus River at Rippon.

The increase in flow from 320 cfs to 642 cfs was much lower than artificial pulses in flow tested in 1993 (400 cfs to 1,400 cfs) and 1994 (350 cfs to 1,200 cfs). The 600 cfs pulse flow in 1995, which was the first artificial pulse of the season, had the same result on juvenile chinook that larger magnitude pulses had in 1993 and 1994. Juvenile outmigrants during 1994 were sampled by CDFG in a rotary-screw trap at Caswell State Park. Catches in the trap in 1994 peaked sharply on April 26 when flows had increased from 360 cfs on April 24 to 794 cfs by April 26 (Figure 22). Flows continued to increase to 1,250 cfs by April 28, but catches had already dropped sharply (Figure 22). Thus, the results in 1994 corroborate the findings in 1995 that migration is stimulated by artificial increases in flow, and that flows substantially less than 1,000 cfs will generate the migratory response.

Figure 22. Daily catch of juvenile chinook in screw trap by CDFG near Caswell State Park in 1994. River flow measured at Ripon.

How long should the pulse flows last to stimulate migration?

The results from sampling in 1995 also substantiate previous findings in regard to the question, “How long should the pulse flows last to stimulate migration?” Cramer and Demko (1993) concluded from trap catches at Oakdale in 1993, and from a review of studies in other streams, that “*the migratory stimulus provided by an increase in flow generally lasts no more than a few days*.” Although flows remained at 580 cfs for 7 days with the first artificial flow pulse in 1995, the abundance index for outmigrants was elevated for only 4 days at the Oakdale trap and 5 days at the Caswell trap. At the end of the 7 days at 580 cfs in 1995, the flow jumped sharply to about 1,300 cfs, but the abundance of outmigrants rose on slightly for 1 day at each trap. Similarly, catches at the Caswll trap in 1994 peaked sharply for 1 day, and then dropped rapidly the next 2 days while flow continued to increase (Loudermilk et al. 1995).

Are there limiting factors before or after the pulse that determine its effect?

Sampling in 1995 confirmed that the flow history immediately preceding a pulse in flow affects the migratory stimulus to juvenile chinook. Although an increase in flow of about 260 cfs on April 8, 1995 stimulated a sharp increase in the number of outmigrant chinook passing

Oakdale and Caswell, there were four other increases in flow of 300 cfs or more during the spring of 1995 that stimuated little or no outmigration. Each of those increases came after the April 8 flow increase. The first was 7 days later when flow increased from 589 cfs to 1,1117 cfs, and the abundance index of outmigrants approximately doubled for 1 day - then dropped back to its previous level. The next three increases of 300 cfs each began after about 10 days of stable flow at 1,300 cfs, and each increase lasted about 48 hours. None of these three flow increases appeared to stimulate any migration.

The greatest increases in chinook outmigrants in each of the two previous years that rotary-screw traps were fished, 1993 and1994, was also associated with the first artificial pulse in flow of the spring season. The second of the two equal flow pulses in 1993, which followed only 5 days after flow began dropping from the first pulse, showed no indication of increasing the number of outmigrants (Cramer and Demko 1993). The second of two equal flow pulses in 1994, which followed 20 days after flow began dropping from the first pulse, was accompanied by a slight increase in trap catches, only equal to about one tenth the increase observed during the first pulse (see Figure 22). We had hypothesised that a delay between pulses was necessary to enable additional juveniles to develop physiological readiness to respond to a migratory stimulus. However, the delay of 20 days between pulses in 1994, appeared to stimulate no more outmigrants with the second pulse than the 7 day delay did in 1995.

There are several physical factors which accompany pulses in flow that we cannot rule out as contributors to the stimulus. These include changes in turbidity, changes in temperature, and date. We only have turbidity data for 1995, and that shows that turbidity increased coincident with each of the pulses that stimulated an increase in outmigrants, and did not increase with pulses that showed no sign of stimulating outmigration. Temperature data in all 3 years of outmigrant trapping indicate that river temperature at Oakdale dropped about 3/F coincident with the first pulse in flow. However, the drop in temperature during 1993 actually preceeded the increase in flow by several days (as a result of cool weather), and the increase in the outmigrant index was least pronounced in that year. In all 3 years sampled, the first artificial pulse in flow occurred between April 8 and April 25.

The mean length of juvenile chinook at the time of the first pulse does not appear to be a controlling factor. The mean lengths of fish captured during the peak outmigration were 88 mm in 1993, 83 mm in 1994 and 60 mm in 1995. This finding is important, because we also found in 1995 that survival of outmigrants increases substantially as the fish increase in size from 60 mm to 80 mm. Therefore, artificial pulses that stimulate outmigration of fish smaller than 80 mm may impair, rather than benefit, their survival.

After multiple years of outmigrant sampling in the Klamath River, Craig (1994) found that mean fork length of chinook measured during peak migration typically exceeded 70 mm, and suggests pulse flows may be of greatest benefit to chinook if pulses occur during times when chinook are 75 to 80 mm in length. Further, he suggests that size may be an easily measured indicator of migration readiness, and may serve to provide water managers and biologists a gage to how best use pulse flows to assist migrations (Craig 1994).

The rate of increase in mean lengths during mid March through May of chinook captured in both the Oakdale and Caswell traps (Figure 23) also suggests that juvenile chinook were stimulated to migrate in 1995 by factors that were independent of fish size. The physiological process of smolting (adaptation for salwater) generally occurs when juvenile chinook are 80 to 100 mm long. Many researchers have noted in different streams that the fastest growing juvenile chinook of a cohort tend to migrate earliest, and that continuous emigration of the largest fish in the population results in a slow increase in the mean length of outmigrants over time. However, this was not apparent in our data in 1995, and the mean lengths of chinook we captured continued to increase at a fairly consistent rate until about the last week in May (Figure 23).

The mean lengths of the chinook captured in the screw traps at Caswell were very similar to the mean lengths captured at Oakdale (Figure 23). The lack of an increase in length between the two sites indicates juvenile chinook that passed the Oakdale site did not pause for additional rearing in the Stanisluas River above Caswell Park. It should be noted that this deduction only applies to the month of May when we had length data from both trapping sites. The mean length of chinook at both sites was already about 90 mm at the beginning of May, which is within the typical size range for smolting of fall chinook. A complete analysis of the data collected at the Caswell trapping station is being completed by the USFWS.

Are findings in the Stanislaus River corroborated by studies elsewhere?

In our 1993 report we sited many examples showing the stimulatory effects of changes in flow on chinook migration. Examples included studies on the Sacramento River in California and the Yakima, Snake and Rogue rivers in Oregon. Here we site a recent study conducted by the USFWS in the Klamath River and a much older study conducted by the CDFG in the Merced River in 1971 and 1972.

From May 1994 through July 1994 the USFWS operated three screw traps in the Klamath River to monitor the effects of pulse flows on juvenile chinook migration (Craig 1994). Craig (1994) found that pulse flow had little effect on the number of migrants i the Klamath River in early May, but had a strong effect in mid June. The flow pulses tested were only 300 cfs increases above an approximate base flow of 2500 cfs. Four 2-day pulses were tested: May 9-10, May 23-24, June 6-7, and June 16-17. Catches of chinook migrants increased after each of last three pulses, but the first pulse followed a natural freshet. That nautal freshet had increased catches, but catches continued to fall through the artificial pulse that began a few days later. Craig (1994) concluded,

> "*The initital migration rates for IGH-released fingerling chinook during 1989 (20 rkm/day), 1991 (9 rkm/day), and 1992 (30 rkm/day) were substantially lower than observed in 1994. The increased rate of migration observed in 1994 indicates that the pulse flow of June 16 benefitted hatchery chinook by dereasing travel time." "It is further suggested that until fish reach appropriate physiological development or 'readiness' to migrate, increased or pulsed flow events may do little other than displace fish downstream.*"

Juvenile chinook during peak catch typically exceeded 70 mm fork length.

The CDFG studied the effects of pulse flows on the outmigration of chinook fry in the Merced River in 1971 and 1972. Outmigrating juvenile chinook were sampled with fyke nets fished at George Hatfield State Park, about one mile up from the confluence with the San Joaquin River. In 1971, the pulse flow lasted almost 5 days in February, and river flow increased from 400 cfs to 1,000 cfs at Crocker-Huffman Dam. During the 1972 pulse period, the flow increased from about 200 cfs to 1,000 cfs at Crocker-Huffman Dam in March. These early dates indicate that many of the fish being sampled were probably fry that had recently emerged from the gravel. The mean lengths of 50 mm and 51 mm were reported for two of the sample days in early March, 1972. In both years, the catches of juvenile chinook increased for a short time only as flow started to recede. After the flow stabilized, the catch of migrants continued at about the same rate prior to the flow increase. The CDFG biologists leading the study concluded:

> *In 1971, increases in the migration occurred for about 48 hours as the flow was receding. In 1972 the migration also increased as the flow decreased, although the increase was for about 24 hours. The flushing flows in March, 1972 may have encouraged some fish to move downstream, but there were substantial numbers remaining in the Merced River after the flush flow"*

(Menchen 1972).

"All evidence collected to date indicate that large numbers of young salmon remain in the nursery area and do not migrate out until they reach a certain size. Smolting in the Merced River appears to be from 75 mm to 110 mm fork length" (Menchen 1972).

OUTMIGRATION TIMING

A substantial portion of the chinook population migrated out of the upper river prior to April, when high precipitation resulted in high turbid flows. Chinook continued to migrate out of the river through May, although in much smaller numbers than observed in March. The fact that chinook continued to migrate out in fair numbers through May indicates that juvenile chinook were not "flushed" out of the river by the sustained flow of 1,300 cfs that began in mid-April.

Our snorkel survey confirmed that most juvenile chinook had left the river by late June. Water temperatures above Knights Ferry were sufficiently cool (<65° F) for continued rearing of juvenile chinook. Our sightings of juveniles while snorkeling above Knights Ferry in July 1993 and June 1994, combined with our catches of yearling chinook in the screw trap in March and April of 1995, indicates that some juveniles remain through the summer in the upper portion of the river and migrate out in winter or spring as yearlings.

The typical outmigration timing of yearling chinook and steelhead/rainbow appears to be earlier in the spring than for subyearling chinook. We captured the first yearling chinook on March 18 and the last on April 9 (see Figure 10). All but one of the 18 smolted steelhead/rainbow were captured before April 15. This time of migration precedes the peak migration window of April 15 to May 15 that has been identified as typical of fall chinook smolts in the Stanislaus River (Loudermilk et al. 1995). Although we were unable to test the trap efficiency for yearling-sized chinook and steelhead/rainbow, the lack of catches after early April should not have been an artifact of reduced trap efficiency. We conclude this, because flows (and thererfore water velocities entering the trap) were higher during April 15-May 31 than they were in late March and early April.

Figure 23. Daily mean lengths of chinook captured by SPCA at Oakdale and by USFWS at Caswell in 1995. USFWS Caswell data are incomplete and in Draft format.

MIGRATION RATE

Given that pulses in flow can stimulate migration under certain conditions, it becomes important to know how long it takes fish to migrate out of the river and then through the Delta. It has been proposed that several short-term actions be taken in conjunction with pulses in flow in order to enhance survival of the juveniles that are stimulated by the pulse. These short-term actions include such things as curtailment of pumping at the state and federal water-export facilities, releases of hatchery production lots, and gravel cleaning to generate turbidity. In order to match the timing of these actions with the time of juvenile fish passage, we need to know how long it takes juveniles to reach varies point after they pass our traps. Our discussion of migration rate is divided under the three key questions we are working to answer.

How Long Does it Take Juvenile Chinook to Migrate out of the Stanislaus River?

Because few of our marked fish were recaptured at the Caswell Trap, we cannot confidently answer this question based on travel times of marked fish. Therefore, we compared the dates that catches peaked at the Oakdale trap with those that catches peaked at the Caswell trap. The dates of peak catches associated with the first pulse in flow (April 8 at Oakdale) were lagged 2 days later at Caswell. This was also true of the smaller increase in catch associated with the jump in flow from about 600 cfs to 1,300 cfs (April 15 at Oakdale). Thus, we conclude that travel time for juvenile chinook from Oakdale to Caswell (24 miles) was 2 days. This equates to 12 miles/day.

This migration rate is slower than observed for juveniles that make longer migrations (over 100 miles), but similar to juveniles making migrations as short as within the Stanislaus River. Muir et al. (1995) demonstrated with PIT-tagged yearling chinook in the Snake River that migration rate began at a slower rate near the rearing area, and then picked up speed as the fish moved downstream. Muir et al. (1995) found that migration rates within the impounded Snake River averaged about 4 miles/day through the first reservoir, but about 14 miles/day through the fourth and fifth reservoir downstream. Craig (1994) found from sampling in the Klamath River
that initial migration rates for fingerling chinook released from Iron Gate Hatchery (RM 190) was 12 miles/day during 1989, 5.6 miles/day during 1991, 18.6 miles/day 1992, and 31 miles/day in 1994.

The migration rate of 12 miles/day for subyearling chinook in the short Stanislaus River appears fast in comparison to the migration rates over longer distances in the Snake and Klamath rivers, especially given that migration rate tends to accelerate with distance traveled.

Therefore, the results from our 1995 sampling are indicative, although certainly not conclusive, that the April 8 pulse in flow may have stimulated juvenile chinook to migrate faster. In the Klamath River, the faster migration rate in 1994 coincided with a 300 cfs increase in flow, and Craig (1994) concluded, "*the increased rate of migration in 1994 indicates that the pulse flow of June 16 benefitted hatchery chinook by decreasing travel time.*"

We did not conduct enough releases of marked fish to distinguish the influence of physical and biological factors on chinook migration rate, but it was evident that migration rate changed during the 1995 season. Fish size and river flow were changing at the same time (see Figure 14). Migration times between Knights Ferry and Oakdale were most protracted when flow was lowest and the abundance of outmigrants was lowest in April. However, the mean size of the outmigrants was also the smallest (62 mm). The migration time was less protracted with each increase in flow (300 cfs to 600 cfs and 600 cfs to 1,300 cfs) and there were peaks in abundance of outmigrants at the same times. The mean length of fish also increased with each subsequent release of fish (see Figure 14), so we cannot separate the possible effects of flow from those of fish size. Migration rate data collected this year will be combined with data collected in future years to determine how river flow, turbidity, temperature and fish size and smolting affect migration rate.

<u>How long does it take juvenile chinook to migrate through the San Joaquin Delta?</u>

None of the fish we marked were captured in the Delta, so inferrences regarding this question must be drawn from either the recoveries of marked fish released elsewhere in the basin, or from differences in the timing of peak catches. We are in the process of obtaining data from the USFWS on recoveries of coded-wire tagged (CWT) chinook in their trawl samples at Chipps Island. We will report our findings from analyses of those data in a future report. A marked group of hatchery fish released in the lower Stanisluas River May 20, 1994 by the CDFG at a flow around 1,200 cfs were recovered 27 miles downstream at the Mossdale Trawl site on May 21. The group traveled the 27 river miles in an average time of 19 hours and 32 minutes, or 33 miles per day (CFDG 1994). The group had a mean length of 94 mm at release. The rapid migration of this group suggests they would have moved through the entire Delta and Bay within a few days.

Will juveniles really stop migrating and be exposed to high mortality in the Delta if pulse flows stop before juveniles pass through the Delta?

This question can best be addressed by data from 1994 when a 3-day pulse in flow stimulated a sharp peak in outmigrants in the Stanislaus River (Loudermilk et al. 1995). Daily sampling by CDFG with a trawl in the San Joaquin Delta at Mossdale showed the same distinct peak in catch that lasted only 1 day, followed by 3 days of slightly elevated catches (Figure). These catches indicate that the fish which were stimulated by the pulse in flow to migrate moved rapidly through the Delta, even though the high flows were sustained in the Delta for only 5 days. There is no indication in the 1995 data that the brief pulse in flow failed to provide high-flow protection through the Delta to the fish it stimulated. In fact, the data from 1995 suggest that the majority of juveniles reacting to the pulse were moving with the leading edge of the increase in flow (Figure).

Figure Mean daily catch of juvenile chinook per 10-minute tow with the kodiak trawl by CDFG at Mossdale in the San Joaquin Delta. From Loudermilk et al. (1995). Streamflow measured at Vernalis by USGS.

SURVIVAL DURING OUTMIGRATION

The two factors that showed the strongest influence on survival of outmigrants within the Stanislaus River during 1995 were fish size and natural-or-hatchery origin. Larger outmigrants survived better than smaller outmigrants, and naturally produced juveniles survived better than hatchery produced juveniles. Other variables such as temperature, flow, turbidity, and migration rate, may also have influeced survival, but the number of mark-recapture tests that we could complete in a single year was only sufficient to distinguish the effects of one or two major factors.

Influence of Size on Survival

The high correlation of survival to mean length for the naturally produced test groups indicated that size of migrants was more influentual in determining survival than the flow, temperature, or turbidity at which those fish migrated. The importance of fish size to survival of the naturally produced test groups was corroborated by large differences in mean size that was apparent between the groups of fish that were released and the survivors that reached the Oakdale trap during the following few days. The mean lengths of marked fish recaptured at Oakdale averaged 11 mm longer than for the fish released at Knights Ferry on March 30, 8 mm longer for those released on April 4 and only 3 mm longer for those released on April 12 (Table 7). Later tests with larger marked hatchery fish showed little difference in the mean size of fish that were released and recaptured (Figure 17). Trap efficiency tests conducted with both natural and hatchery chinook indicated that the trap efficiency was similar for all sizes of subyearling chinook we sampled in 1995. The differences we found between the mean siizes of fish we released, and those of the fish that reached our trap suggest that fish under 75 mm in length had a reduced probability of survival during outmigration. Further, it appears that once fish were about 75 mm or longer, there was little size-related difference in survival.

It is possible that some of the smaller sized fish within the first two release groups of natural migrants may have remained upstream to rear longer. This could have given the appearance in our data at the Oakdale trap that the smaller fish had died, but only if those smaller fish eventually lost their marks or remained upstream until after our sampling finished. Both of these possibilities are very small. We verified with our live cage tests that mark retention was essentially 100% after 21 days. We also verfied with our snorkel surveys that few juvenile chinook remained upstream of our trap by the end of June when our sampling terminated.

Influence of Hatchery-or-Natural Origin

Our mark-recapture tests indicated that natural migrants survived at many times the rate of hatchery migrants. The survival index for migration from Knights Ferry to Oakdale (14.6 miles) for natural migrants that averaged 76 mm fork length was 66.7% in contrast to a highest survival among hatchery fish released at Knights Ferry of only 8.6% for a group that averaged 106 mm fork length. Similarl to these findings in the Stanislaus River, Raymond (1988) found the smolt-to-adult survival of spring chinook from the upper Columbia and Snake rivers was generally 3 to 5 times geater for wild fish than hatchery fish during the 1980's. Although the size of fish among our test groups of natural migrants showed a dramatic effect on survival, hatchery fish in the test groups were larger, on average, than any of the natural migrant test groups (see Figure 17). The substantial difference in survival between hatchery and natural test groups indicates that use of hatchery fish to estimate migration survival is likely to produce results that are not applicable to wild fish. In fact, Raymond (1988) found in the Columbia that smolt-to-adult survival rates of wild spring chinook improved substantially following many years of work to improve passage survival at dams, but comparable survival rates of hatchery fish remained unchanged.

One might even construe from the survival indexes estimated for the five hatchery groups released at OBB that migration survival is negatively influenced by flow, but we see no reason why this would be true. Four of the five releases were conducted at high flows ranging from 1,315 cfs to 1,479 cfs, and produced relatively uniform survival ranging from 7.6% to

14.3% (Table 7). In contrast, the flow was only 671 cfs for the last group of hatchry fish released at OBB (June 14), and the survival index was substantially higher at 73.9%. The cause of the higher survival for the first test group is not clear. These fish were slightly larger than previous test fish (Figure 17), but there was no tendency among any of the hatchery groups for the mean lengths of chinook released to be shorter than the mean lengths of the fish recaptured (Figure 20). It is possible that the unusual results with hatchery fish may reflect sampling error. For example, if the hatchery fish remained in schools as they passed Oakdale, the lateral position of those schools in the water column as they passed our trap would have determined whether they were caught at a high or low rate. Additional replicates of mark-recapture tests with hatchery and wild fish will be needed in the future before the cause of differences in survival between hatchery and wild fish can be understood.

We lack enough data to properly determine the extent that other physical and biological factors influence survival of juvenile chinook during outmigration, although it is certainly less than the influence of fish size and natural-or-hatchery origin. Survival rate data collected this year will be combined with data collected in future years to determine how river flow, turbidity, temperature and migration rate affect survival rate.

CONCLUSIONS

1. An increase in flow from 320 cfs to 578 cfs in 1 day, resulting from release of stored water is sufficient to stimulate a sharp increase in the number of juvenile chinook migrating out of the Stanislaus River.

2. The first sharp increase in flow during April is likely to stimulate a substantial outmigration of juvenile chinook. This stimulus is likely to last less than 5 days at a given point in the river, regardless of changes in flow.

3. Juvenile chinook that are stimulated to migrate by a sharp increase in flow appear to migrate completely out of the Stanislaus River in about 2 days, and then continue through the Delta, at least to Mossdale, on the leading edge of the pulse in flow.

4. After the first major peak in number of outmigrants in April, the number of juvenile chinook stimulated to migrate by any additional sharp increases in flow is likely to be small in comparison to the first peak.

5. Even when the mean length of juvenile chinook is only 60 mm, they can be stimulated to migrate rapidly downstream by a sharp increase in flow.

6. The majority of juvenile chinook had already migrated out of the Stanislaus River by April 15 in 1995, and they may do so in other years also.

7. An increase in flow from 1,000 cfs to to 1,300 cfs following 10 days after a previous increase in flow does not stimulate additional outmigration.

8. As in 1993, sustained flows of 1,300 cfs did not flush juvenile chinook from the river and some remained through May.

9. The survival of naturally-produced juvenile chinook during migration increases rapidly as their size increases up to at least 75 mm.

10. Surivival of juvenile chinook from Merced Hatchery during migration through the Stanislaus River appears to be much lower than for naturally-produced chinook.

11. Some juvenile chinook remain in the upper river over summer and migrate out in late winter and early spring as yearlings.

12. Rainbow trout are present in the Stanislaus River and a portion of the population appear to be anadromous. Their low abundance indicates they could result from spawning of stray hatchery steelhead.

RECOMMENDATIONS FOR FURTHER STUDIES

1. Investigate use of Passive Integrated Transponder (PIT) tag technology to determine the feasibility of large scale PIT tag study. PIT tags allow computerized tracking of individual fish and allow for the direct measurement of growth rates, migration rates, and survival rates. In a cooperative effort with the CDFG and USFWS, we can determine the migration rate and survival of juvenile chinook out of the Stanislaus River and through the Delta. Marked natural and hatchery fish should be released at Knights Ferry and recaptured at Oakdale by SPCA, at Caswell by the CDFG and/or USFS, at Mossdale by the CDFG and at Chipps Island by the USFWS. Additional sampling for recovery PIT tags should be conducted at the export pump fish facilities.

2. In order to increase downstream recoveries of marked fish to a useful level, steps must be taken to increase the catch rate at Caswell screw trap. A catch rate of 5% of migrants at the Caswell trap would make it possible to estimate chinook migration rate and survival through the Stanislaus River. The channel at the screw trap should be modified so that water velocities entering the trap are sufficient to attract juvenile chinook into the trap. An application for a USACE permit to modify the channel should be completed soon by the agency responsible for the lower trap.

3. SPCA and staff of CDFG and USFWS should meet in the fall of 1995 to determine sampling objectives, methods, and coordination for field studies to be conducted in 1996.

4. Outmigration sampling in 1996 should include snorkel/seine surveys of juvenile chinook below Oakdale. These surveys would establish whether or not chinook migrating past our screw trap early in the year are moving out of the river or rearing downstream.

5. Discuss with CDFG and USFWS the feasibility of electrofishing during the 1996 outmigration season to determine composition and distribution of predator species and the extent they prey on juvenile chinook.

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APPENDICES